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S. Obenauer
S. Luftner-Nagel
D. von Heyden
U. Munzel
F. Baum
E. Grabbe

Screen film vs full-field digital mammography: image quality, detectability and characterization of lesions

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S. Obenauer (✉) · S. Luftner-Nagel
D. von Heyden · F. Baum · E. Grabbe
Department of Radiology,
Georg-August-Universität Göttingen,
Robert-Koch-Strasse 40, 37075 Göttingen,
Germany
e-mail: soben@med.uni-goettingen.de
Tel.: +49-551-398965
Fax: +49-551-399606

U. Munzel
Department of Medical Statistics,
Georg-August-Universität Göttingen,
Robert-Koch-Strasse 40, 37075 Göttingen,
Germany

Abstract The objective of this study was to compare screen-film mammography (SFM) to full-field digital mammography (FFDM) regarding image quality as well as detectability and characterization of lesions using equivalent images of the same patient acquired with both systems. Two mammography units were used, one with a screen-film system (Senographe DMR) and the other with a digital detector (Senographe 2000D, both GEMS). Screen-film and digital mammograms were performed on 55 patients with cytologically or histologically proven tumors on the same day. Together with these, 75 digital mammograms of patients without tumor and the corresponding previous screen-film mammograms not older than 1.5 years were reviewed by three observers in a random order. Contrast, exposure, and the presence of artifacts were evaluated. Different details, such as the skin, the retromamillary region, and the parenchymal structures, were judged according to a three-point ranking scale. Finally, the detectability of microcalcifications and lesions were compared and correlated to histology. Image contrast was judged to be good in 76%, satisfactory in 20%, and unsatisfactory in 4% of screen-film mammograms. Digital mammograms were judged to be good in 99% and unsatisfactory in 1% of cases. Improper exposure of screen-film system occurred in 18% (10% overexposed and 8% underexposed). Digital mammograms were improperly exposed in 4% of all cases but were of acceptable quality after post-processing. Artifacts, most of them of no significance, were found in 78% of screen-film and in none of the digital mammograms. Different anatomical regions, such as the skin, the retromamillary region, and dense parenchymal areas, were better visualized in digital than in screen-film mammography. All malignant tumors were seen by the three radiologists; however, digital mammograms allowed a better characterization of these lesions to the Breast Imaging Reporting and Data System (BI-RADSZZZ;) categories (FFDM better than SFM in 23 of 165 vs 9 of 165 judged cases in SFM). In conclusion, digital mammography offers a consistent, high image quality in combination with a better contrast and without artifacts. Lesion detection in digital images was equal to that in screen-film images; however, categorization of the lesions to the BI-RADS classification was slightly better.

Keywords Full-field digital mammography · Breast neoplasms · Image quality

Introduction

Mammography is the best method for detecting early stage breast cancers. In recent years there have been a lot of improvements in mammography. One promising development is the introduction of digital technique [1, 2]. It was first introduced into interventional procedures using small field-of-view digital detectors, the charge-coupled device receptors (CCD). Due to limitations of this technique, the introduction in mammography was very slow [3, 4, 5, 6, 7, 8, 9, 10, 11, 12].

Recently, full-field digital mammmography detectors have been introduced which are based on flat-panel digital detectors. These systems have improved low-frequency resolution compared with storage phosphor systems and have improved DQE compared with both storage phosphor and screen-film systems. In this study, our goal was to compare the image quality, the detectability, and characterization of lesions for this new flat-panel digital detector to those of a screen-film system.

Materials and methods

Mammography systems

A screen-film state-of-the-art system (Senographe DMR) and a new digital mammography unit (Senographe 2000 D, both General Electric, Buc, France) are used for daily routine. The digital system is built on the DMR platform. Both systems have a dual-track X-ray tube with a molybdenum and a rhodium anode and a 0.03-mm molybdenum and a 0.025-mm rhodium filter, respectively. The focal spot size is 0.3 mm for standard mammograms and 0.1 mm for spot views. The detector consists of a thin-film amorphous silicon integrated circuit on a single, full-size glass substrate and a cesium iodide (CsI) scintillator coating on top of the photodiodes. The image detector properties are shown in Table 1 [13]. After exposure, the images are displayed on a high-resolution monitor (2×2.5 K) of the review workstation. For this study, however, only hardcopies were used. A dedicated mammographic screen-film combination (UM-MA film with UM-MA fine screen, Fuji Photo Film, Tokyo, Japan) was used for the screen-film mammograms.

The digital images were processed automatically applying a “thickness compensation” algorithm and printed using a high-resolution laser printer (Model Scopix LR 5200, Agfa, Leverkusen, Germany). Pixel size of the printer was 40 µm with a high resolution of 8,512×10,348 pixels at the format 14×17 in. in 11 s. The modulation depth was 16 bit.

Table 1 Description of the detector of the Senographe 2000 D

Detector type	Amorphous silicon flat panel
Scintillator	CsI
Active area	19×23 cm
Detector matrix	1,900×2,300 pixels
Pixel size	100 µm
Fill factor	75%
Detective quantum efficiency	55% (28 kVp, 0 lp/mm)
Spatial resolution	5 lp/mm
Dynamic range	>10,000:1
Digitization depth	14 bits

Patients

After the permission of the ethics committee and patient consent, 55 women between 35 and 81 years of age with a mammographic lesion suspicious of breast cancer were examined with both screen-film and digital technique. The corresponding mammograms with the same projections were obtained on the same day or a few days after histological or cytological verification of cancer. As a control group, 75 patients, ranging in age from 39 to 79 years with “screening” mammograms, were included in this study comparing the previous screen-film mammograms, not older than 1.5 years, to the current digital mammograms. Additional follow-ups of these patients revealed no suspicious lesion.

Evaluation

All screen-film and digital mammograms were reviewed independently by three observers. The mammograms were coded and all information and patient data were deleted. The images were presented in random order. The observers were given a protocol to consider image quality, image contrast, and the exposure quality by using a three-point scale. The presence of artifacts was noted. Detectability of details in the cutaneous and subcutaneous region (with, without spot, or not visible), the parenchymal structures, and the retromamillary space was evaluated with a three-point scale. All three-point scales were divided into “good,” “satisfactory,” and “unsatisfactory.” The type of breast tissue according to the American College of Radiology (ACR) was determined. The detectability and characterization of microcalcifications and lesions were evaluated concerning their localization, size, and form. Furthermore, the observers had to decide on a final diagnosis, to judge the lesions, and to assign them to one of the Breast Imaging Reporting and Data System (BI-RADSZZZ;) classifications (I–V) [14]. The percentage of quality for screen-film and digital images were calculated. The BI-RADSZZZ; classifications of proven cancers were correlated to histological diagnoses.

Statistical analysis

Because the ratings were ordinal, a nonparametric analysis-of-variance-type test for the two-factor block design was used [15]. The considered factors were “image” (either analog or digital) and “observer.” Due to significant image–observer interactions, separate analyses for each observer were performed by using a paired-rank test [16].

Results

Image contrast was judged to be good in 76%, satisfactory in 20%, and unsatisfactory in 4% of screen-film mammograms. Digital mammograms were considered to be good in 99% and unsatisfactory in 1% (Fig. 1a). Inadequate imaging in SFM occurred in 18% of cases (10% overexposed and 8% underexposed). Digital mammograms were improperly exposed in 4% of all cases but were of acceptable quality after post-processing. Artifacts were found in 78% of screen-film and in none of the digital mammograms (Fig. 1b). Different anatomical regions, mentioned above, were better visualized in digital than in screen-film mammography (Figs. 1c, 2, 3). The comparison of corresponding screen-film and digital mammograms revealed significant differences concern-

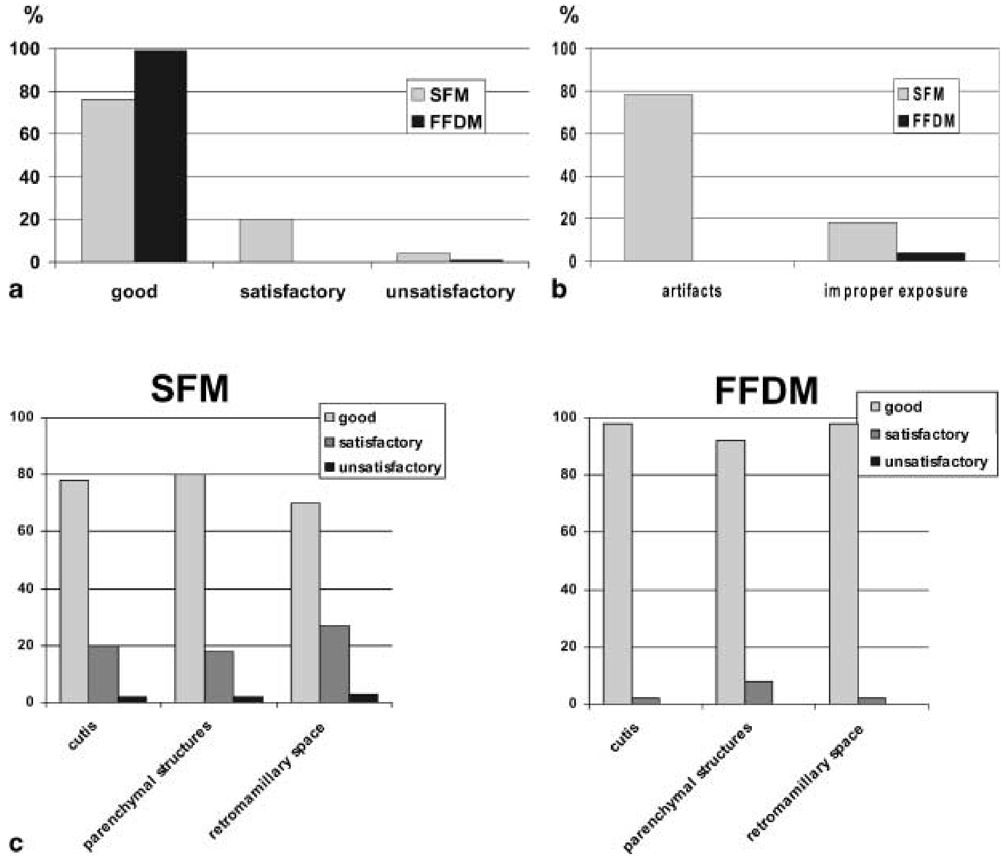


Fig. 1a–c Image quality characteristics of the screen-film technique (*SFM*) vs the full-field digital mammography (*FFDM*). **a** Contrast; **b** image quality; **c** detail detectability of cutis, parenchymal structures, retromamillary space

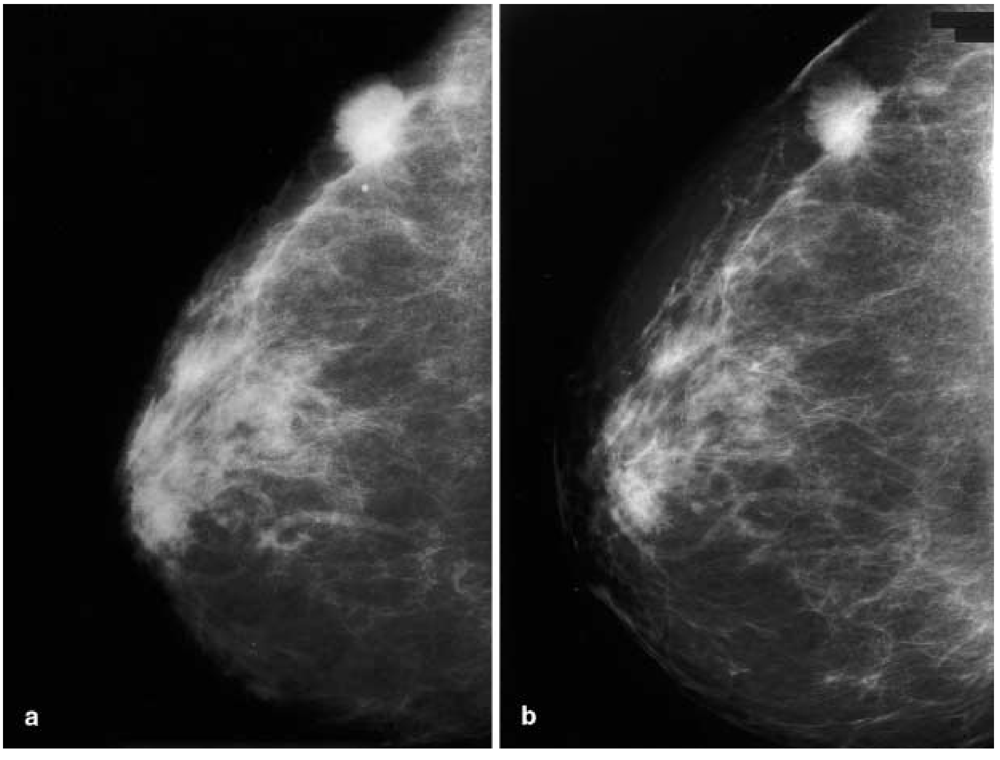
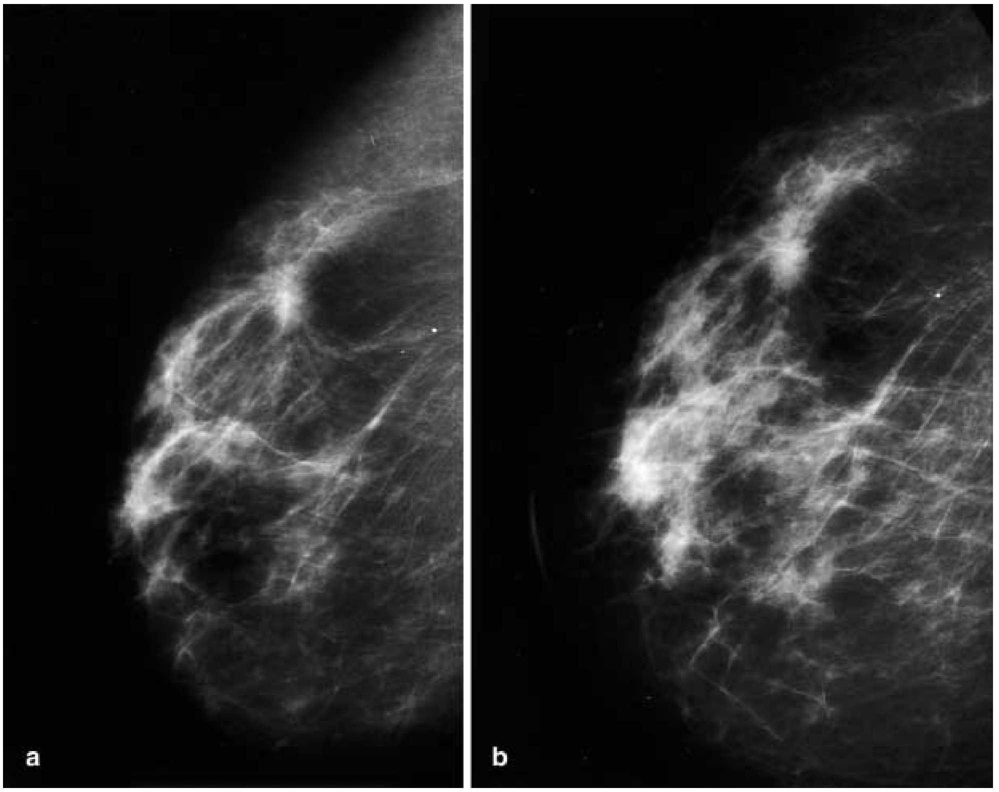


Fig. 2 A 45-year-old woman with a breast tissue type ACR 1 and a 2-cm spiculated mass in the right upper level easily detected with both techniques. Note that the skin thickening is more apparent in digital technique (**b**) than in screen-film technique (**a**)

Fig. 3 A 55-year-old woman with a spiculated mass in the left upper level detected in both techniques. BI-RADSZZZ; classification was more accurate in digital (**b**) than in screen-film technique (**a**) by two of the three observers



ing the image quality, contrast and sharpness, the presence of artifacts and the detectability of details within the skin, the subcutaneous area, the parenchymal structures, and the retromamillary space with a *p*-value <0.05 (Table 2).

Observer 1 judged the breast tissue to be ACR type 1, 2, 3, or 4 in 11, 35, 48, and 6% in screen-film technique, and in 13, 40, 42, and 5% in digital technique, respectively. Observer 2 considered the breast tissue to be ACR type 1, 2, 3, or 4 in 9, 45, 38, and 8% in screen-film, and in 9, 48, 40, and 3% in digital technique. Observer 3 judged the tissue types 1, 2, 3, or 4, in 18, 38, 39, and 5% in screen-film, and in 17, 46, 35, and 2% in digital technique, respectively.

All malignant tumors were seen by the three radiologists leading to histology and consequently to the final diagnosis. The BI-RADSZZZ; classifications of the histologically proven malignant lesions differed in the screen-film and digital mammograms in 11 cases for observer 1, in 9 for observer 2, and in 12 for observer 3. All other histologically proven lesions were assigned to the same BI-RADSZZZ; category regardless of technique. The diagnostic accuracy in the evaluation of malignant lesions by observer 1 was better in digital images in 6 cases, and better in screen-film images in 5 cases. For observers 2 and 3 diagnostic accuracy was better in the digital images in 8 and 9 cases, and better in the screen-film images in 1 and 3 cases, respectively. Digital

Table 2 Comparison of screen-film vs digital mammograms concerning the different ranking parameters (three observers, paired-rank test)

Variable	Observer	*p*-value[a]
Image quality	1	<0.001
	2	0.066
	3	0.023
Contrast	1	<0.001
	2	0.004
	3	<0.001
Sharpness	1	<0.001
	2	0.004
	3	<0.001
Darkness	1	<0.001
	2	0.033
	3	0.054
Image noise	1	0.012
	2	0.566
	3	0.556
Artifacts	1	<0.001
	2	<0.001
	3	<0.001
Skin	1	<0.001
	2	<0.001
	3	<0.001
Retromamillary space	1	<0.001
	2	<0.001
	3	<0.001
Parenchymal structures	1	<0.001
	2	<0.001
	3	<0.001

[a] Significant at $p<0.05$

mammograms allow a slightly better detectability and characterization of lesions according to the BI-RADS-ZZZ; classification than screen-film mammograms. The difference concerning the final diagnosis, however, was not significant.

Histology of the suspicious lesions in 55 patients revealed 42 invasive ductal carcinomas (25 pT1, 14 pT2, 1 pT3, 2 pT4 tumors), 6 invasive lobular carcinomas, 1 radial scar, 1 radial scar with areas of lobular carcinoma, 4 ductal carcinomas in situ (DCIS), and 1 recurrence of an invasive ductal carcinoma.

Discussion

The National Cancer Institute has designated digital mammography as the imaging technology with the greatest potential for improving the detection and diagnosis of breast cancer [6].

The Senographe 2000D is a new full-field digital mammography system based on a flat amorphous silicon array and CsI scintillator, which has been used for our clinical daily routine work since November 1999. A potential limitation of this system is its lower spatial resolution of 5 lp/mm in comparison with that of 12–15 lp/mm for SFM. The minimal pixel size needed for digital mammography remains a subject of debate. Several studies have demonstrated that despite the lower limiting spatial resolution, detectability of microcalcifications on CR images was equal to that on SFM [7, 8, 11, 17]. Although these CR systems have a pixel size (100 µm) equal to the flat-panel system tested in this study, these systems have a much lower DQE. This results in higher noise for the CR systems compared with the flat-panel system at the same radiation dose. In addition, although to the limiting spatial resolution which is determined by the pixel size of 5 line pairs/mm for both systems, the flat panel system has much higher modulation transfer function at all spatial frequencies below the limit. This higher resolution is a result of the CsI phosphor which produces a higher-resolution image than the storage phosphors. In our study all malignant tumors could be detected by the three radiologists. Therefore, this study design is not usable for the evaluation of sensitivity, specificity, and accuracy for malignancies of the two systems because evident tumors were judged; however, the digital mammograms demonstrated a slightly better categorization into the BI-RADSZZZ; classification. All of the studies involving CR emphasize the importance of optimized image processing for detail visualization in digital mammography. The image processing technique implemented by our system, called “thickness compensation,” results in an optimized image quality which allowed hardcopies to be printed without additional image post-processing by the radiologists. Further advantages of the digital technique are the wider dynamic range, the higher contrast-detail detectability, and the better detective quantum efficiency [6, 10, 17, 19]. All these factors lead to better visibility of the skin, the retromamillary space, and the parenchymal structures in digital mammograms, even for the breast with dense tissue according to ACR type 4. A thickening of the skin can be an important sign of breast cancer in a dense breast (ACR type 4). Our study showed that the ACR type was judged lower in digital than in screen-film mammography independent of the reader; however, this result was not significant. The reason for this result could be the wider dynamic range and the potential of post-processing allowing the adjustment of the window and level in very dense breast tissues. The overall noise levels were determined to be similar for both modalities.

Dust artifacts as well as artifacts due to the film developer are often seen in screen-film but not in digital mammograms. A lot of these artifacts found in SFM had no diagnostic rol Repeated mammograms due to over- or underexposure were no longer necessary with the digital technique. Whereas the subjective interpretation of over- and underexposure in SFM was very high (ca. 18%), and we did not use measurements to prove false exposure, this could be an explanation for the high rates. Post-processing (windowing and leveling) of digital mammograms provided images of acceptable to good quality in all cases.

A retrospective patient study of 591 patients with 1116 digital mammograms revealed an average glandular dose of approximately 1.5 mGy independent of breast thickness [20]. In comparison with screen-film mammography, this value is located at the lower area of radiation exposure of SFM using a speed class system 12.

Conclusion

In conclusion, the flat-panel digital system was superior to screen-film mammography in image quality, detail visibility, image exposure, and artifacts. Lesion detectability and characterization according to the BI-RADS-ZZZ; classifications in digital images was equal or even superior to that in screen-film images. These results indicate that the better contrast detectability and the ability to do image processing highly compensated for the limitation in spatial resolution. Whether there is a difference in the ability to accurately determine microcalcification shape still needs to be investigated in more extensive studies.

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